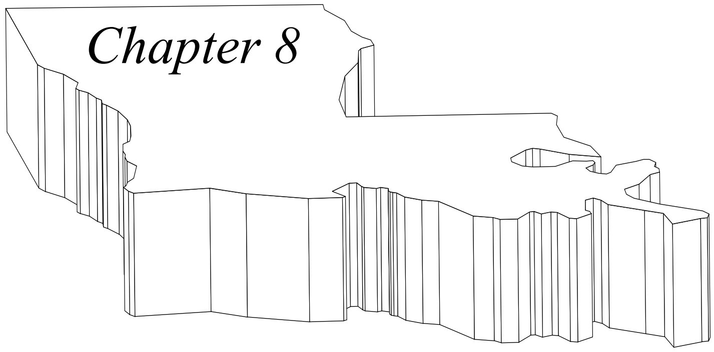
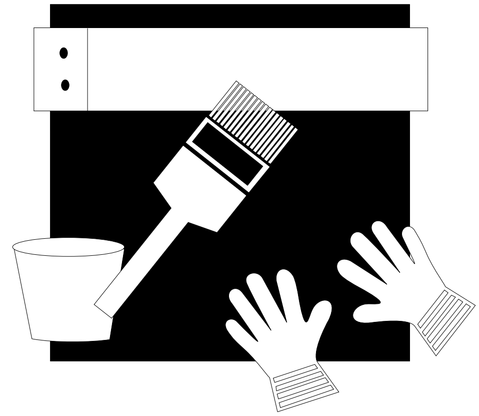
Chapter 8





Duct Design and Sealing

THE PROBLEM OF DUCT LEAKAGE

Studies conducted throughout the country have found that poorly sealed ductwork is often the most prevalent and yet easily solved problem in new construction. Duct leakage contributes 10 to 30% of heating and cooling loads in many homes. In addition, duct leakage can lessen comfort and endanger health and safety.

Locating ducts in conditioned space eliminates many problems with leakage. They are installed in *chases* — framed air passageways situated behind the ceiling or wall finish. However, these chases are often connected more directly to unconditioned space than interior space. Therefore, it is important to seal these areas completely from unconditioned spaces.

The heating and cooling contractor should use proper materials when sealing ductwork — in particular, duct sealing mastic. Duct insulation does not provide an airtight seal. To ensure ducts are tight, have your HVAC contractor conduct a duct leakage test.

The 1995 Model Energy Code and the International Energy Conservation Code require that HVAC contractors must use mastic and mesh tape to seal leaks. This new provision reflects the universal recognition that duct leakage not only is a cost effective energy efficiency measure, but it also improves comfort and most importantly, makes our homes healthier places in which to live. Chapter 3 on Concepts explains some of the health risks of leaky ductwork in detail.

Duct Leaks and Air Leakage

Forced-air heating and cooling systems should be *balanced* — the amount of air delivered through the supply ducts should be equal to that drawn through the return ducts. If the two volumes of air are unequal, then the pressure of the house can be affected. Pressure imbalances can increase air leakage into or out of rooms in the home.

Pressure imbalances can create dangerous air quality in homes including:

- ❐ Potential backdrafting of combustion appliances such as fireplaces, wood stoves and gas burners.
- ❐ Increasing air leakage from the crawlspace to the home, which may draw in dust, radon, mold, and humidity.
- ❐ Pulling pollutants into the air handling system via return leaks.

Typical causes and concerns of pressure imbalances, addressed more fully in Chapter 3, include:

- ❐ HVAC systems with excessive supply leaks can cause homes to become depressurized, which may cause backdrafting of combustion appliances inside the home.
- ❐ HVAC systems with excessive return leaks can cause homes to become pressurized and create negative pressures around the air han-

dling unit; which may cause combustion appliances near the air handling unit to backdraft.

❒ Homes with central returns can have pressure imbalances when the interior doors to individual rooms are closed:

❍ The rooms having supply registers and no returns become pressurized, while the areas with central returns become depressurized.

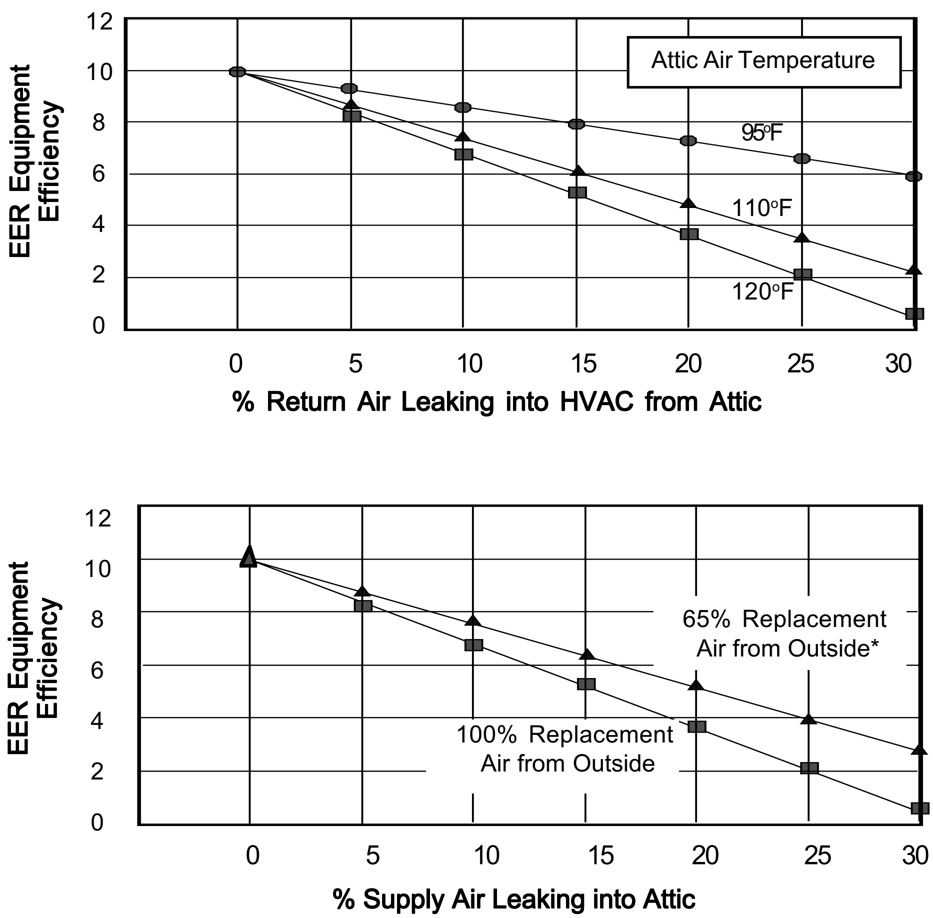
❍ Often the returns are open to living rooms with fireplaces or combustion appliances.

❍ When these spaces become sufficiently depressurized, the flues will backdraft.

❒ Tighter homes with effective exhaust fans, such as kitchen vent hoods, clothes dryers, and attic ventilation fans, may experience negative pressures when these ventilation devices operate.

Figure 8-1 shows the impact of return and supply leaks on equipment efficiencies in attic HVAC systems. For example, a HVAC systems having 15% return leakage in a moderately hot attic (120^{o}F) can suffer a 50% drop in efficiency — from EER (Energy Efficiency Ratio) 10 to EER 6. The EER measures the number of Btu's per hour of cooling a watt of electricity provides. In addition, the supply air temperature may rise and not provide adequate comfort on hot outside days.

Figure 8-1
Efficiency Losses Due to Attic Return and Supply Leaks



* 65% Replacement Air from Outside means that of the air lost from the supply duct, 65% leaks into the house from outside, while the other 35% finds its way from the supply leak back into the house.

Likewise, the second chart shows the drop in performance of cooling systems with supply leaks. When HVAC supply ducts leak air to the outside, the return side of the system still requires the full amount of air back. It will depressurize the house in an effort to pull the lost air back into the system. In a home with 15% supply leaks, if 100% of the replacement air comes from outside, the efficiency of the system will drop from EER 10 to about EER 5.0, a 50% reduction in efficiency. Note that duct leakage of only 5% results in efficiency losses of 10% to almost 20%.

Thus, leaky ducts can reduce equipment efficiencies dramatically. They can also lower supply air temperatures in winter, which may pose major comfort problems for the occupants.

Sealing Air Distribution Systems

Duct leakage should be eliminated. In standard construction, many duct seams are not sealed or are poorly sealed with ineffective materials such as cloth "duct tape," unrated aluminum tape, or similar products with lower quality adhesives not designed to provide an airtight seal over the life of the home. Use only the following products for sealing the components of the air distribution system:

- ❐ Nontoxic duct sealing mastic with fiberglass mesh tape — highly preferred — may add $20 to $55 to the cost of a $5,000 system, but provides a lifetime seal.

TESTING FOR DUCT LEAKAGE

The best method to ensure airtight ducts is to pressure test the entire duct system, including all boot connections, duct runs, plenums, and the air handler cabinet. Much like a pressure test required for plumbing, ductwork can be tested during construction so that problems can be easily corrected.

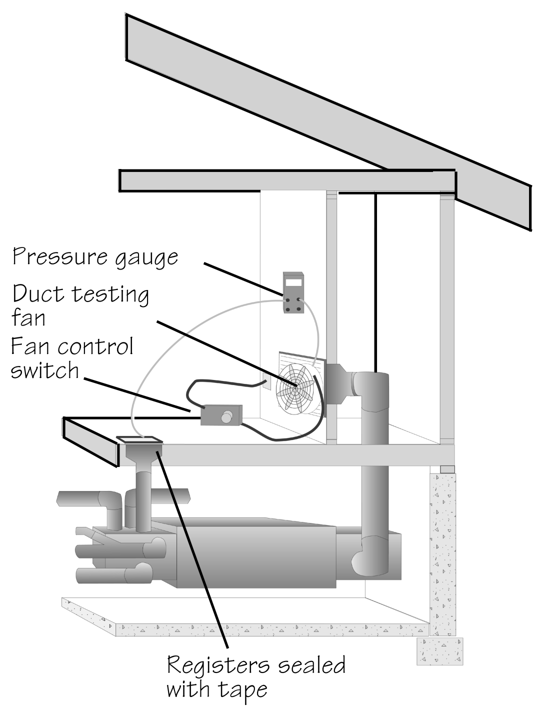
In most test procedures, a technician temporarily seals the ducts by taping over the supply registers and return grilles. Then, the ducts are pressurized to a given pressure — usually 25 Pascals using a duct testing fan. This pressure is comparable to the average pressure the ducts experience when the air handler operates.

While ducts are pressurized, the technician can read the total duct leakage of the HVAC system.

Some energy efficiency programs require that the cubic feet per minute of duct leakage measured at a 25 Pascal pressure (CFM25) be less than 3% of the floor area of the house. For example, a 2,000 square-foot house should have less than 60 (2,000 x 0.03) CFM25 of duct leakage.

Another test is to use a blower door (described in Chapter 3) and a duct testing fan together to measure duct leakage after construction is complete. This procedure gives the most accurate measurement of duct leakage to the outside of the home. A duct leakage test can usually be done in about one hour for an average -sized home.

Figure 8-2
Duct Test on Return Grille



- ❐ Aluminum tape with a UL-181 A or B rating or "mastic" tapes with improved adhesives.
  - ❍ Tape must be installed properly to be effective.
  - ❍ The duct surface must be clean of oil and dirt, and the tape must fully adhere to the duct with no wrinkles.
  - ❍ A squeegee must be used to remove air bubbles from beneath the taped surface.
  - ❍ Costs only $4 to $5 more than “silver tape," which has an inferior adhesive.
- ❐ High quality caulking or foam sealant.

Proper sealing and insulation of the ductwork in unconditioned areas requires careful attention to detail and extra time on the part of the heating and air conditioning contractor. The cost of this extra time is well worth the substantial savings on energy costs, improved comfort, and better air quality that an airtight duct system offers.

The easiest answer to the question of where to seal air distribution systems is “everywhere.” A list of the key locations is as follows:

High priority leaks

- ❐ Disconnected components, including takeoffs that are not fully inserted, ducts that have been dislodged, tears in flex-duct, and strained connections between ductwork (visible where ducts bend where there is no elbow).
- ❐ The connections between the air handling unit and the supply and return plenums.
- ❐ All of the seams in the air handling unit, plenums, and rectangular ductwork — look particularly underneath components and in any other tight areas. Also, seal the holes for the refrigerant, thermostat, and condensate lines. Use tape rather than mastic to seal the seams in the panels of the air handling unit so they can be removed during servicing. After completing service and maintenance work, such as filter changing, make sure the seams are retaped.
- ❐ The return takeoffs, elbows, boots, and other connections. If the return is built into an interior wall, all connections and seams must be sealed carefully. Look especially for unsealed areas around site-built materials.
- ❐ The takeoffs from the main supply plenum and trunk lines.
- ❐ Any framing in the building used as ductwork, such as a “panned” joist in which sheet metal nailed to floor joists provides a space for conditioned air to flow. It is preferable to avoid using framing as a part of the duct system.
- ❐ The connections near the supply registers — between the branch ductwork and the boot, the boot and the register, the seams of the elbows, and all other potential leaks in this area.

Moderate priority leaks

- ❐ The joints between sections of the branch ductwork.

Low priority leaks

- ❐ Longitudinal seams in round metal ductwork.

Figure 8-3
Sealing Flex-duct Collar with Mastic

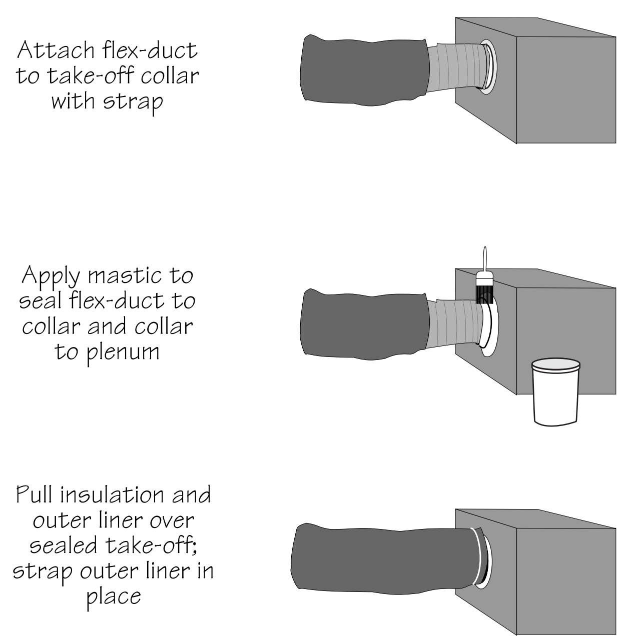
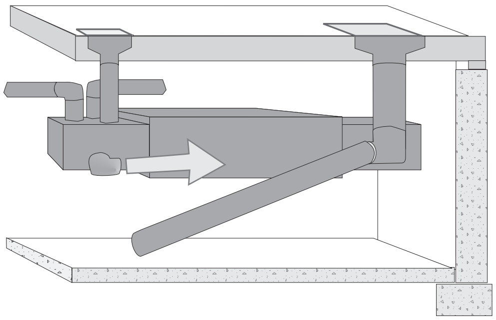
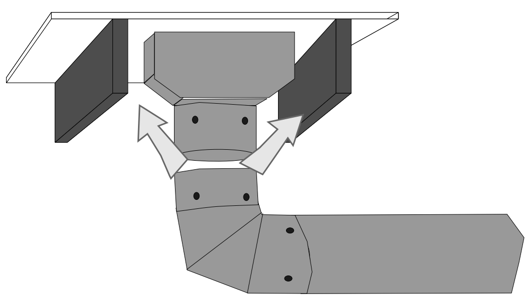


Figure 8-4
Disconnected Ducts Are High Priorities



Dislodged supply duct

Ducts can become disconnected during initial installation, maintenance, or even normal operation. They should be checked periodically for problems.



Disconnection at boot

Sometimes, disconnected ducts can be hidden behind the insulation. Look for kinks or curves where there is no elbow.

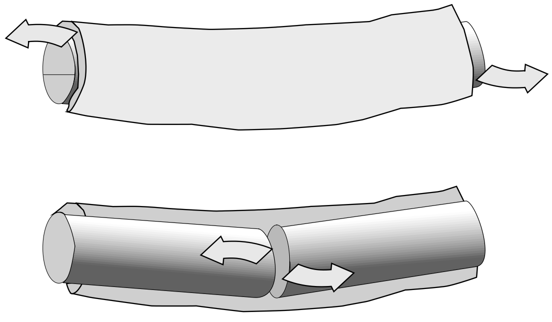
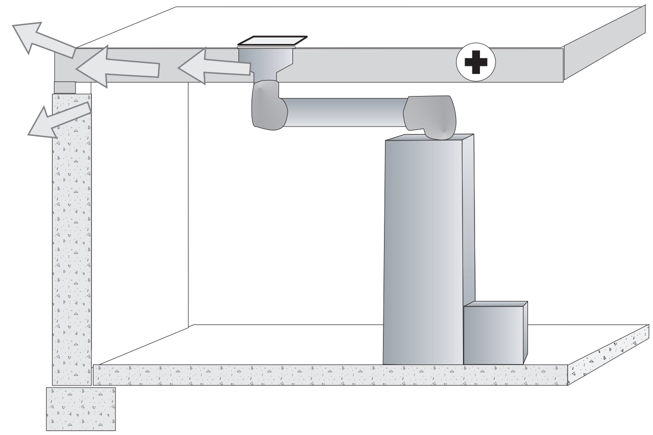
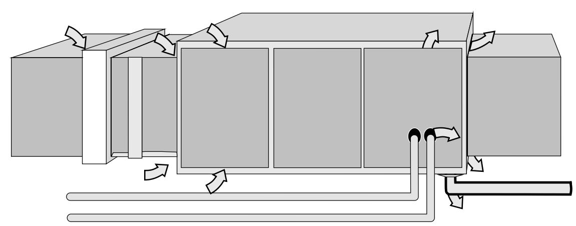


Figure 8-5
Duct Leaks in Inside Spaces



Although this supply duct is theoretically in conditioned space, the supply leaks pressurize the band joist area and air leaks to the outside. The best solution — seal all duct leaks and all building envelope air leaks

Figure 8-6
Seal All Leaks in Air Handling Unit



Virtually all air handling cabinets come from the factory with leaks, which should be sealed with duct-sealing mastic. Removable panels should be sealed with tape.

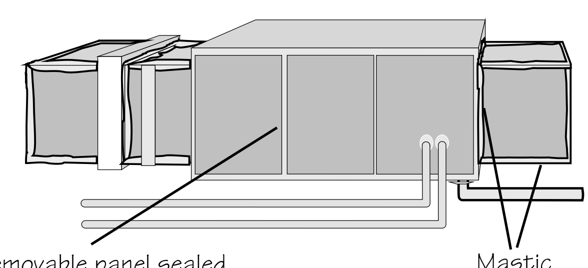
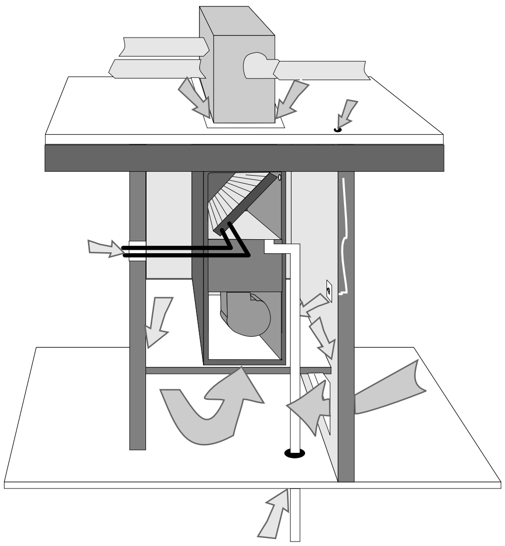
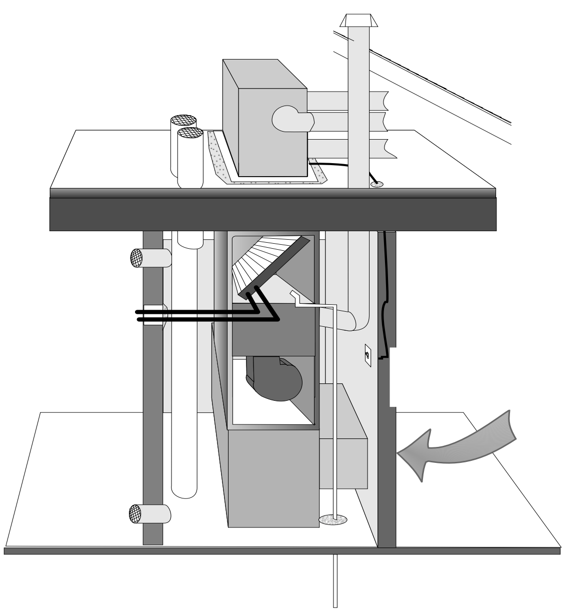


Figure 8-7
Shelf-Mounted Systems Without Returns



Non-ducted returns can severely depressurize mechanical room closets, not only sapping the system's efficiency, but also creating ideal conditions for backdrafting and other air quality problems.



The return should be connected to the home via well sealed ductwork. All holes from the mechanical room closet to other spaces should be completely sealed.

Figure 8-8
Seal All Leaky Takeoffs

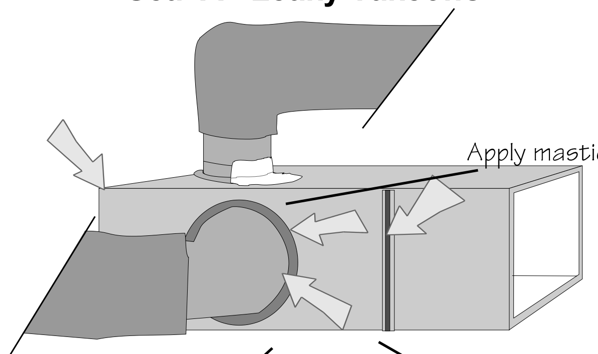
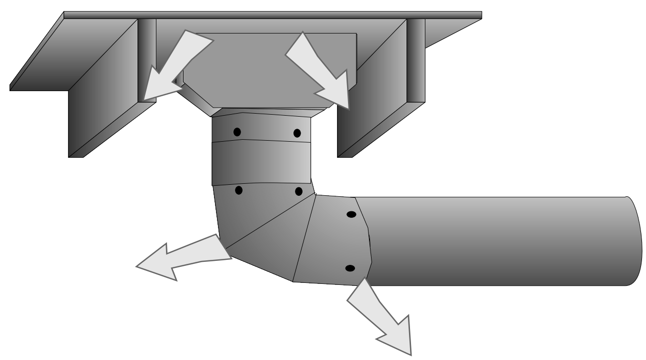
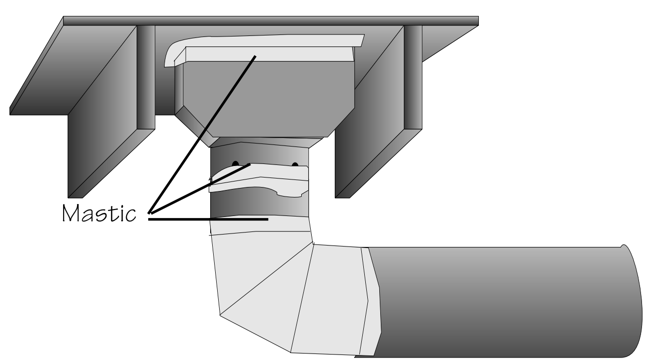


Figure 8-9
Sealing Leaky Boots





Use mastic to completely seal all leaky seams and holes. Use mesh tape with mastic to cover cracks over 1/8-inch wide.

Duct Design

Duct Materials

The three most common types of duct material used in home construction are *metal, fiberglass duct board*, and *flex-duct*. Both metal and fiberglass duct board are rigid and installed in pieces, while flex-duct comes in long sections.

Flex-duct is usually installed in a single, continuous piece between the register and plenum box, or plenum box and air handler. Be careful not to tear the soft lining material. The flex-duct must also not be pinched or constricted. Long flex-duct runs can restrict air flow, so they must be designed and installed carefully. Flex-duct takeoffs, while often airtight in appearance, can have substantial leakage and should be sealed with mastic. Always select duct insulation with a shiny, metal foil exterior covering to reduce radiant heat gain.

Round and rectangular metal duct must be sealed with mastic and insulated during installation. It is important to seal the seams and joints first, because the insulation does not stop air leaks.

Metal ducts often use fiberglass insulation having an attached metal foil vapor retarder. The duct insulation should be at least R-6, and the vapor retarder should be installed to the outside of the insulation — facing away from the duct. The seams in the insulation are usually stapled together around the duct and then taped. Duct insulation in homes at least two-years old provides visible clues about duct leakage — when the insulation is removed, the lines of dirt in the fiberglass often show where air leakage has occurred.

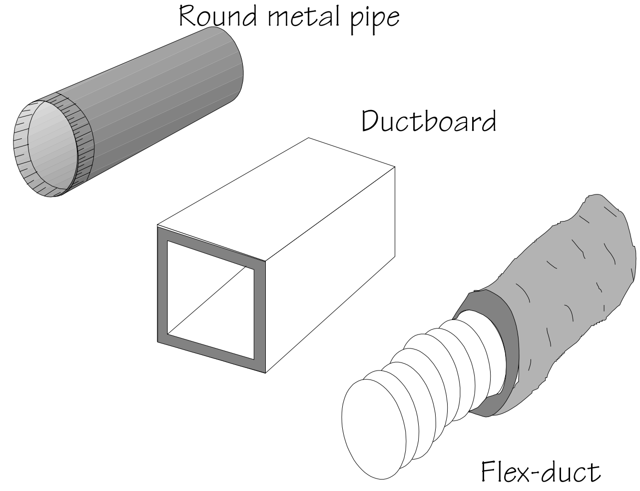
Sometimes, rectangular metal duct used for plenums and larger trunk duct runs is insulated with duct liner, a high density material that should be at least 1-inch thick. Many homeowners have concerns about the long term effects of the duct liner exposed to the air flowing through the system. They prefer to insulate the outside of the ductwork, rather than the inside.

Sizing and layout

The size and layout of the ductwork affects the efficiency of the heating and cooling system and comfort levels in the home. The proper duct size depends on:

- ❐ The estimated heating and cooling load for each room in the house.

Figure 8-10
Types of Ductwork



- ❐ The length, type, and shape of the duct.
- ❐ The operating characteristics of the HVAC system (such as the pressure, temperature, and fan speed).

The lower temperature of the heated air delivered by a heat pump affects the placement of the registers. A heat pump usually supplies heated air between 90°F and 110°F. At these temperatures, air leaving registers may feel cool. They should be placed so as to avoid blowing air directly onto people. Fuel-fired furnaces typically deliver heated air at temperatures between 110°F and 140°F, 40°F to 70°F greater than room temperature, so placement of the supply registers is less important to maintain comfort.

HVAC contractors usually locate supply registers on outside walls under or above windows, and place return registers towards the interior, typically in a central hallway.

Some builders of energy efficient homes have found little difference in temperature between interior areas and exterior walls because of the extra energy features. Locating the supply registers on exterior walls is not as necessary to maintain comfort. These builders can trim both labor and material costs for ductwork by locating supply and return ducts near the core of the house.

In standard duct design, virtually all supply ducts are 6-inch flex-duct or round metal pipe. Most standard designs have only one return for each floor.

The standard approach of using all 6-inch branch ducts with a single return works for some homes, but can create operating problems for others, including:

- ❒ Too much heating and cooling supplied to small rooms, such as bathrooms and bedrooms with only one exterior wall.
- ❒ Inadequate airflow, and thus, insufficient heating and cooling, in rooms located at the greatest distance from the air handler.
- ❒ Over-pressurization of rooms when interior doors are closed.

The heating and cooling industry has comprehensive methods to size supply and return ductwork properly. These procedures are described fully in *Manual D, Duct Design* published by the Air Conditioning Contractors' Association.

Unfortunately, few residences have ductwork designed via *Manual D*. The primary "design" is determining, usually via intuition, how many 6-inch ducts to install in each room.

Figure 8-12 shows the size ductwork *Manual D* would specify for a small home. The design is vastly different than the typical all 6-inch system. The advantage of proper design is that each room receives air flow proportionate to its heating and cooling load, thus increasing overall comfort and efficiency.

The following recommendations, while no substitute for a *Manual D* calculation, should improve system performance:

- ❒ If two rooms have similar orientation, window area, and insulation characteristics, but one room is considerably farther from the air handling unit than the other, consider increasing the size of the ductwork going to the farthest room.
- ❒ Bonus rooms over garages often need additional or larger supplies.
- ❒ Rooms with large window areas may warrant an extra supply duct, regardless of room size.
- ❒ Likewise, large rooms with few windows, only one exterior wall, a well insulated floor, and conditioned space above may need only one small duct.
- ❒ Ductwork air flow can be adjusted to meet each room's needs using manually controlled dampers and an air flow measurement device.

Figure 8-11
Comparison of Air Flow in Different 6-inch Ducts

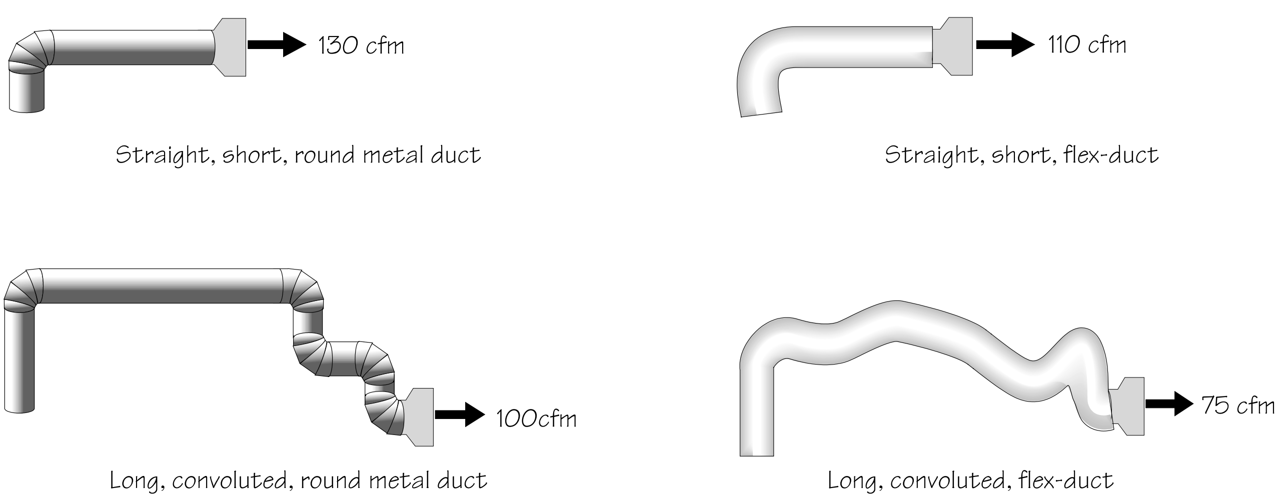


Table 8-1
Checking System Air Flow

Use this form to check the ductwork for proper sizing:

Step 1: Find the system's cooling capacity in tons.

Step 2: Multiply the tonnage in Step 1 by 400 to get the desired total air flow in cubic feet per minute (cfm) = 400 x ________ tons = ___________ cfm total

Step 3: Check the supply air flow

a. Determine the number of supply registers connected to 4", 6", 8", and 10" branch ducts .

b. Fill in column 2 in the chart below. Then multiply the number of ducts by the air flow and put the result in Column 4. Add the flows in Column 4. If the total is within 10% of the actual air flow (from Step 2), the supply ductwork is probably adequate.

Step 4: Check the return air velocity

a. Measure the total area of all return grilles = ________square inches

1. Branch Duct Size	2. Number of Supply Registers	3. Air Flow per Register (cfm)	4. Duct Air Flow (cfm) Step 2 x Step 3
4"		50	
6"		100	
8"		200	
10"		400	
Total Air Flow			cfm

b. Multiply the total area in Step 4a by 70% = _______square inches

c. Divide the answer to Step 4b by 144 to get square feet of area = ________ square feet

d. Write the total air flow here = ________ cfm (total cfm in chart above)

e. Divide the air flow in Step 2 by the area inStep 4c to get the estimated return air velocity:

airflow _______ / area ________ = ________ ft/minute

If the velocity is over 650 ft/ minute, add a return or increase the size of a return.

Example:

Home with 2.5 ton system, one 4-inch, eight 6-inch, and one 8-inch branch supply ducts.

Step 1: 2.5 tons

Step 2: 400 x 2.5 = 1,000 cfm

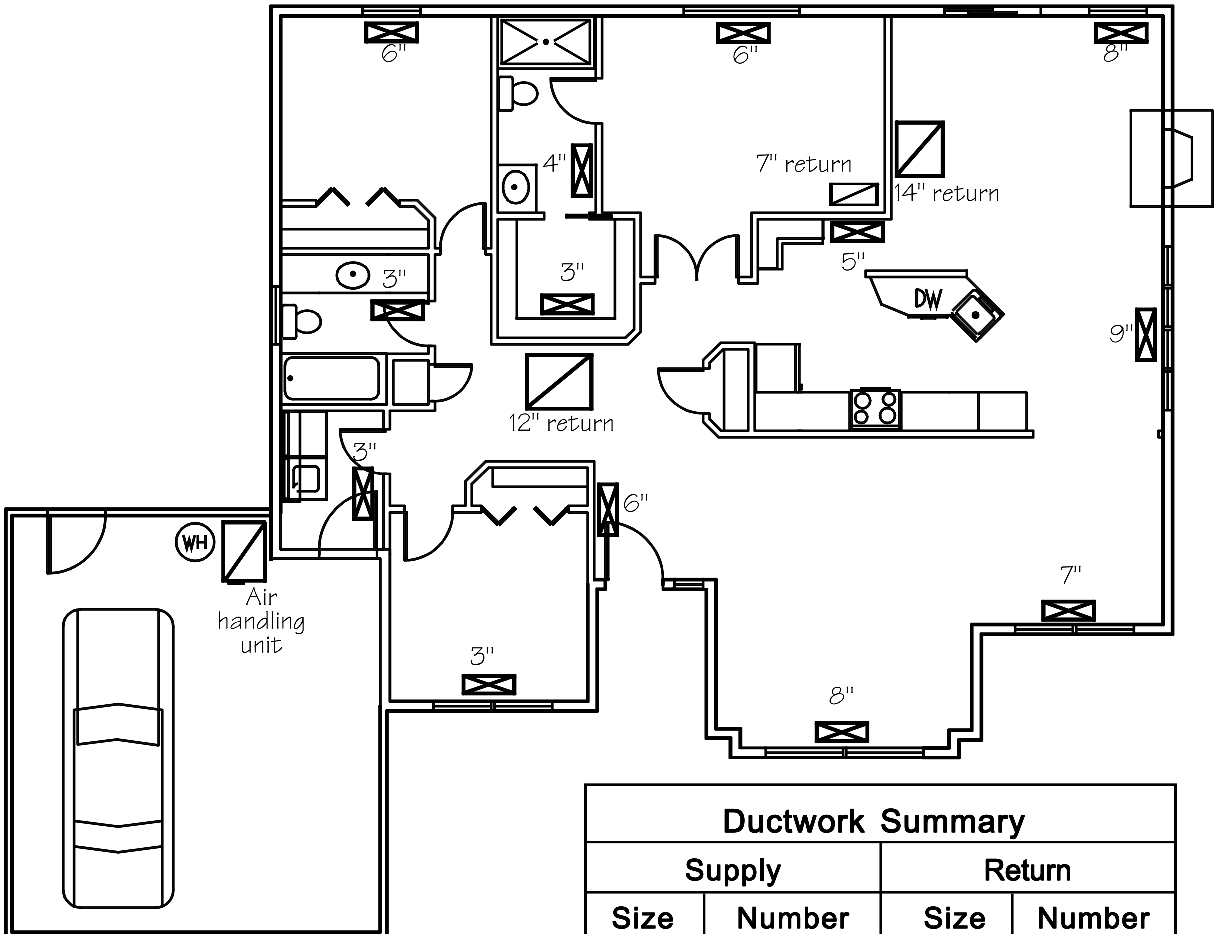
Step 3:

1. Branch Duct Size	2. Number of Supply Registers	3. Air Flow per Register (cfm)	4. Duct Air Flow (cfm) Step 2 x Step 3
4"	1	50	50
6"	8	100	800
8"	1	200	200
10"	0	400	
Total Air Flow			1,050 cfm

Since 1,050 cfm is within 10% of system air flow, there should be sufficient supply ductwork.

Figure 8-12
Duct Design Using Manual D

(In standard duct installation, all supply registers would be 6 inches in diameter, and there would be a single 14-inch to 16-inch return.)



Ductwork Summary			
Supply		Return	
Size	Number	Size	Number
3"	4	7"	1
4"	1	12"	1
5"	1	14"	1
6"	3		
7"	1		
8"	2		
9"	1		